

SYSTEM FOR SEPARATING OIL FROM WATER

This application is a continuation-in-part of Application Serial Number 10/050,712 filed 01/18/02, which is directed to a system comprising a method and apparatus for separating oil and water from industrial oily wastewaters, and is incorporated herein by way of reference. In particular, the present system is directed to the separation of water from machining cutting coolant oils, die release agents, oily wash waters, and other emulsified oils, wherein the filter element is systematically and economically cleaned.

Statement Regarding Federally Sponsored Research Or Development

- NOT APPLICABLE

Background of the Invention

The above-identified prior Application which is incorporated herein by way of reference, teaches of the present need for the provision on-site of effective systems for the economic separation of water from oily wastewater. The prior application also discusses current systems and their respective limitations. The prior Application teaches the effective use of cross-flow ceramic filters by means of which the desired oil/water separation is effected; and discloses a system for membrane surface cleaning uniquely using various cleaning chemicals in sequence both in cross-flow across the membranes as well as chemical back-pulsing through the membranes so as to maintain it in effective operation.

Brief Summary of the Invention

The purpose of the present invention is to mechanically treat oily water, containing low concentrations of oil in the order of 1/2 % to 6% by volume,

typically, to separate the oil from such oily water, by extracting substantially oil-free water as a permeate.

The present invention provides a significantly improved and simplified apparatus having at least one processing “ring”, (formerly referred to as a “loop”), and utilizes filter modules that are significantly improved over the current industry standard. The subject filter modules per se are automatically cleaned in-situ using various cleaning solutions in sequence and on demand as part of the regular operation of the processor. As a consequence, unprecedented levels of filtration and treatment of waste oily waters are readily achieved.

Multiple filter modules can be economically integrated with a single PLC (Programmable Logic Controller) to provide a range of filtering capacities to suit the bulk disposal requirements of respective manufacturing plants.

Oily water continuously circulates around the ring, as permeate water is extracted (and sent to drain), until the oil concentration in the ring is increased to just under 35% oil. At this concentration, the volume of oily liquids and the corresponding costs of their disposal are significantly reduced.

This 30+% oil concentration generated by the processor can be further concentrated to about 90-95% oil by gravitational settlement, simply leaving it in a tank for the water to settle out. Sulfuric acid can be used in a tank to “shock” this oily concentrate emulsion which will hasten the break up of the emulsion. The resultant oily water that “drops out” of the oily concentrate can be simply reintroduced into the processor, and re-processed. The present process may achieve processor output oil concentrations as high as about 40 volume percent.

However, filter membrane contamination tends to escalate at oil concentrations higher than 40%. In the case of a typical raw-feed oil/water concentration of 2% oil, the achievement of an oil concentration of 40% means that approximately 95% of the initial water content has been stripped from the feed and sent to drain or otherwise re-utilized, with corresponding savings in disposal costs of the residual oily concentrate that is left.

The subject filter module per se is the same as that disclosed in the prior application, having a stainless steel housing containing a ceramic cross-flow filter element, wherein the radial clearance between the ceramic filter element and housing is effectively minimized, primarily for the purpose of achieving a reduction in the respective volume/volumes of cleaning solution necessary for effective reverse flow and forward flow of the cleaning solutions used to flush clean the membrane surface of the filter module or modules.

The cleaning liquids in most instances are returned to the respective reservoir, for re-use, with consequent annual savings in the cost of cleaning chemicals. Certain cleaning liquids, such as hydrogen peroxide are unsuitable for re-use, and are disposed of after one use.

After a cleaning cycle the respective cleaning liquid is returned to its respective reservoir by the use of an air purge acting through the top of the ring, which drives the cleaning solution downwards and out of the ring bottom and back to its reservoir. The same air purge applied at the ring top is also used as the initial displacement medium before any filling/re-filling of the ring.

Liquid materials removed from the ring may be either oily water, cleaning solutions, or rinse waters used after each cleaning cycle.

As in the prior application, the filter element per se has a permeable sintered cylindrical alumina body having a number of circular bores ("lumens") in mutually parallel relation with the primary axis of the cylinder. Each of the lumens has a peripheral surface membrane filter coating of fine zirconium and/or titanium oxide crystals, which permits the cross-flow passage of water therethrough, when subject to a pressure differential in the order of about 35 to 60 psi (pounds per square inch), while simultaneously serving to block the passage of oil, which flows along the face of the membrane, thus staying within and re-circulating through the lumens and the ring.

The membrane surfaces have a pore size in the ultra-filtration range of about 0.01 micron, however slightly larger or smaller pore size membranes can be used.

Pressures higher than 60 psi tend to lead to fouling of the membrane surface. The concentration of oil circulating in the ring increases steadily, as the water content is depleted, with clear permeate water leaving the ring after passing through the membrane filter. Oily water is continuously added as a make-up volume to replace this permeate water.

Periodically a valve opens, directing concentrated oily water out of the ring, and allowing in-flow of make-up oily water, to effect a lowering of the oil concentration in the ring.

It is necessary to keep the oil concentration in the ring at or under 35% oil concentration by volume.

The feed of oily water to the filter ring is automated by way of a pressure tank having a centrifugal pump in-feed that operates in response to the operation of low-level and high-level float switches located within the tank, with tank pressurization being controlled by an air inlet regulator and valve working in conjunction with an air dump valve. The operation to refill the pressure tank is controlled by the PLC controller which activates air in/out valves and the re-fill pump, based on the logic states of the two (high and low) float switches inside the pressure tank as it cycles during normal processing operations.

An improved oscillating cleaning system, relating to the cleaning cycle/cycles is adopted, which provides the capability of through-flushing cleaning solutions through the pores of the membrane of the filter element/elements in both directions. A settable timer within the PLC may initiate the cleaning cycles.

Alternately and preferably, a cleaning cycle is initiated when the permeate production rate falls below a preset minimum flow, averaged over time, as monitored by a paddle-wheel style flow meter.

When a cleaning cycle is initiated, the ring is drained of oily water by air blow down, then filled with tap water, which is re-circulated for a short time as a rinse, drained with air blown-down, and the ring then filled with an appropriate cleaning solution

A double O-ring seal is used in the subject filter modules, to seal the ceramic filter element to its stainless steel housing, to ensure that no oily residue passes

from the ring side of the processor to the clear water permeate side of the system, as a consequence of repeated pressurized back and forth pulsing of cleaning fluids, previously found on occasion to have caused displacement of singular O-ring seals.

The subject system includes "power-failure" provisions which incorporate a normally-open air safety valve that is energized during normal operation of the system, and held in a closed condition, thereby excluding safety air pressure.

In the event of a power failure the safety valve becomes de-energized and opens, thereby admitting (safety) air pressure, which applies back-pressure to the permeate (filtered, oil-free) water that would normally flow out of the system. A normally-closed valve directing permeate water to drain is held open during normal processing and is teed to the air safety valve. During an electrical power-off situation this permeate drain valve closes, allowing the air safety valve (now open) to back-pressure permeate water in a reverse direction to the normal system pressure, to protectively suffuse the filter membrane surface with oil-free permeate. Oil droplets in the oily water would otherwise foul the filter membrane surface on a shut-down, by their tendency, under system pressure, to move into the membrane, in the absence of circulatory flow cross-flow in the ring due to the loss of power and consequent loss of pumping action.

The "oscillating" cleaning system has two small volume reservoirs associated with the ring. One reservoir is located at the ring top position and the other is located at the module top position, connected to the clean water permeate out-line. The primary purpose of these two reservoirs is to receive cleaning solutions

which are oscillated between one and the other. Cleaning solutions are moved through the membrane surfaces from one reservoir to the other by means of air pressure. Each reservoir contains a stainless steel float switch to signal the PLC controller when cleaning solution has passed from one reservoir as it empties, through the membrane, and into the opposite reservoir until it fills.

Upon start-up from a totally empty condition, the PLC will cause the processor ring and its related top located reservoir to fill with water, until the float switch within that reservoir is activated.

In carrying out the cleaning cycles, the various cleaning solutions also fill to the same level in the ring top position reservoir, thereby assuring that the ring is filled with liquid before the start-up of the re-circulation pump that moves liquid around the ring. Filling of the system is controlled by the PLC working in combination with the float switches.

One function of the PLC controller is to monitor the output rate of clear treated permeate water from the ring. This output rate is averaged over a period of time, on account of normal fluctuations in the rate of filtration that may take place other than as a consequence of fouling of the filter during normal operation.

Initiation of a cleaning cycle takes place when the clear water output rate falls below a predetermined (and re-settable) value, as recorded by the PLC.

The preferred cleaning cycle method involves the admission of a selected one of the available cleaning fluids from its respective reservoir, to fill the ring and the top mounted ring reservoir with the fluid. The ring is then isolated from all inward or outward flow of liquids by closure of the access solenoid valves, and the ring

pump is run. Due to the absence of liquid transfer (input or output from the ring), the temperature of the cleaning fluid within the sealed ring rises quite rapidly, due to frictional heat generation. During this phase of the cleaning process, there is effectively no flow through the filter membrane, with the cleaning solution merely being pumped around the ring, along the lumens of the filter so as to heat the ring and the solution within. Upon reaching a predetermined elevated temperature, as determined by a temperature transducer, the cleaning cycle per se commences. The cleaning fluid is passed from the full ring reservoir under air pressure and outwardly through the filter membrane and moves to the other reservoir which is venting to atmosphere. This movement of hot solution continues until the fluid has transferred between the reservoirs, by traversing the filter membrane.

The two sight glass reservoirs provide a visual reference of each transfer cycle, with one glass emptying while the other fills. After an appropriate delay, for the cleaning liquid to carry out its cleaning function, the transfer is then reversed, by reversal of the pressure gradient, to effect a to-and-fro or “see-saw” transfer of the cleaning liquid between the ring reservoir through the membrane surfaces and into the module reservoir. Operation of the reverse transfer or see-saw oscillation of cleaning solution is controlled by actuation of the liquid level sensor float switch in the “receiving” reservoir, by way of a signal to the PLC. A temperature transducer connected to constantly sense the ring liquid temperature sends a 4-20 mA (milli Amp) signal to the PLC which determines when to initiate cross-membrane flow once the correct elevated temperature for

the cleaning solution re-circulating in the ring is reached. This cycle is repeated a (adjustable) number of times, to complete one of the available phases of filter cleaning.

It is usual practice to flush the ring with clean water before and after each chosen cleaning solution cycle.

The system has a number of cleaning solutions each with its respective solution reservoir, and a control system to enable selective sequential administration of the solutions, in accordance with demonstrated need. The sequencing of these chemical cleaning operations is operator-selectable, either on-site or from a remote control location, by use of a communication modem. During all these cleaning sequences the ring pump is still running and heating the ring to even higher temperatures which facilitates cleaning efficiency. When a predetermined safe upper temperature limit for the respective cleaning liquid is reached, the signal from the temperature transducer causes the PLC to shut down the ring pump, putting a stop to the temperature rise. With the pump stopped, the oscillation of cleaning solution between the two reservoirs continues until the pre-set number of oscillations is achieved.

While a system employing up to four different cleaning solutions is disclosed herein, it will be understood that systems having a greater or a lesser number of such cleaning solutions are contemplated, and considered as coming within the ambit of this invention.

The system incorporates a number of pressure relief valves, to relieve untoward pressure spikes. One source for generating such a pressure spike may be the

use of a cleaning solution that has the capability of gassing-off, associated with its cleaning activities, thereby creating a high rate of pressure build-up, which is accentuated by the elevated ring temperatures generated during cleaning. An example of potential high rate gas generation is during the use of hydrogen peroxide, used as a cleaning agent for certain stubborn contaminants, wherein rapid oxygen gas release can occur. A contributing factor to this generation of high rate pressure spikes is the heating up of this cleaning solution and its attack on organic contaminants which takes place due to the cleaning solution being repeatedly circulated around the process ring. during the initial part of the cleaning cycle.

Control of the operation of the subject system in separating water from oily water, and also in the operation of an available sequence of cleaning cycles is effected by the PLC, which commences the process sequence when oily water is made available for processing, i.e. when it is deposited into the main waste oily water storage tank, which causes a master float switch to rise and transmit a signal to the PLC.

The PLC re-boots itself automatically, in the event of a power loss/power return situation.

In addition to operating the separation process, and the processing ring cleaning cycles, the PLC can also store production data, which can be transmitted to a central facility via telephone, enabling remote monitoring and control of system operation.

The PLC may monitor other processing site parameters such as storage tank volumes, leaks, and error situations.

A single remote operator can readily monitor/control many such systems.

In operation, the PLC is programmed to initiate a cleaning cycle/ cycles when the process output rate falls to a pre-determined threshold low value.

When the filter starts to foul (plug-up), with consequent reduced throughput, the process threshold low rate occurs, initiating a signal to the PLC. The PLC activates a first cleaning cycle that is normally adequate to restore the process rate to a value above the threshold value. In the event, after a predetermined lapsed time, that the process rate is still too low, and fails to meet the predetermined threshold permeate water volume throughput, the PLC then initiates a second-phase cleaning cycle, which is a repeat of the first cleaning cycle, but followed afterwards with a different, second cleaning solution cycle. If this again proves inadequate to restore the process rate, a further, third cleaning solution is cycled through the ring, and so on. In light of the significance of effective cleaning on the efficient operation of the cross-flow filter process, the apparatus has particular provisions for enabling systematic cleaning cycles; and the apparatus is connected so as to minimize loss of the respective cleaning fluids. This leads to very significant cost savings in cleaning chemicals, and is ecologically beneficial. To that end, the fill-up (up-flow) and drain-down flow path junctures are profiled and inclined, to concentrate the flow of liquid, particularly in the case of cleaning liquids, and in the case of the up-flow filling portion of the cycle, to obviate air-lock blockage by the entrapment of air bubbles.

The subject system is very flexible in terms of providing a range of filter arrangements with a corresponding available range of annual throughputs of treatment volumes.

Thus different systems, each mountable within the standard cabinet, consisting of one or more rings containing standard ring elements, may have annual nominal throughputs as shown (in litres of clean output water per year):

	Low	High
1) 1-pump and 1-filter	- 500,000 L/year	- 1,000,000 L/year
2) 2-pumps and 2-filters	- 1,000,000 L/year	- 2,000,000 L/year

Furthermore it is envisioned that two filters may be run in series in each ring driven by one re-circulation pump. This scenario should give the following annual production rates of permeate water:

	Low	High
1) 1-pump and 2-filter	- 800,000 L/year	- 1,500,000 L/year
2) 2-pumps and 4-filters	- 1,600,000 L/year	- 3,000,000 L/year

A second filter module placed in series and driven by the same pump as the first filter module will give a diminished return of produced permeate water compared to the first filter due to a drop in pressure which occurs as the re-circulating oily water exits the first filter. It is water pressure that drives permeate water through the filter, and depending on the ceramic filter element type, its array of lumens (bores), and their diameters, differing Delta P (pressure drop) values will obtain. Wider (and fewer) lumens within a filter element of equal diameter will prove less

restrictive to the passage of re-circulating oily water and hence will offer less resistance and create less pressure drop.

From the two charts above and in terms of equivalent filter performance, these production figures demonstrate a membrane filter rate substantially in the range of 1 to 2 million litres per year per square meter of filter membrane surface area, a value significantly in excess of present normal expectations with existing technologies when treating contaminated chemically bound oily emulsions containing dirt and particulates.

Filter (“flux”) flow rates have been consistently achieved by the subject process, in the range of 250 to 350 LMH (litre/ *square* metre/ hour), with such oily emulsions.

The main processor’s PLC controller is capable of controlling many more processing rings than the two rings used in the standard set-up. The PLC can control outlying, electrically and hydraulically connected “slave” processing rings housed in a separate cabinet/cabinets.

In such a multiple set-up individual rings would process oily water until the permeate flow meter of an individual processor ring signals that it requires a cleaning sequence. The cleaning sequence would then be initiated for that ring. Any other processor ring subsequently signaling for a cleaning cycle would simply “wait in line” until the preceding ring had completed its cleaning cycle.

In this way one PLC controller can accommodate many processors.

The plant is substantially fail-safe, and environmentally friendly.

While the present disclosure is directed to the separation of water from oily water by way of an improved mode of cross-flow filtration, it will be understood that the contributions of the present invention may readily apply to mixtures of other materials, and their separation.

Brief Description Of The Several Views Of The Drawing

Certain embodiments of the present invention are shown by way of illustration, without limitation of the invention thereto, other than as set forth in the present claims, reference being made to the accompanying drawings, wherein:

Figure 1 is a schematic front elevation of a processing apparatus in accordance with the present invention, having a pair of rings, each with a single cross-flow filter unit;

Figure 1A is a perspective cross-section of the filter, taken at A-A of Figure 1;

Figure 2 is a representational view similar to Figure 1, of a subject apparatus having a single cross-flow filter unit in its ring, and mounted within a cabinet;

Figure 3 is a schematic side elevation, in partial section, of the oily water feed reservoir portion of the Figure 1 embodiment;

Figure 4A is a schematic side elevation view similar to Figure 2, showing a cabinet-mounted two-ring, filter system embodiment. The left ring is a single filter embodiment and the right ring is a double filter embodiment;

Figure 4B is a schematic elevation as a rear view of Figure 4A, showing the processor system support apparatus, located in the reverse side of the cabinet;

Figure 5 is a plan view of the cabinet contents of the Figure 4A and 4B embodiment;

Figure 6 is a diametrical section, in elevation of one of the sight-glass ring reservoirs;

Figure 7 is a schematic side view of a detail portion of the cleaning solution reservoirs and rinse water circulation system; and,

Figures 8-12 are block diagrams showing the basic steps of the subject process.

Detailed Description of the Invention

In the following description, the term “normally-closed” indicates that in a power-off condition the valve in question would close. Correspondingly the term “normally-open” indicates that in a power-off condition the valve in question would open.

Referring to Figure 1, two rings 20 are shown, each having a single filter unit 22. The rings 20 are generally housed within the same cabinet (not shown) and are serviced from a series 24 of cleaning liquids, C1 through C4. The description and numerals applied to the left hand ring 20 are generally identical for the right hand ring 20.

In Figure 1A, the location of the lumens within the filter 22, and their membrane filter coatings 25 are shown, together with the permeate water (filtrate) collection annulus 23.

Each ring 20 includes an electric motor 26 driving a ring re-circulation pump 28, which normally circulates oily water through the central lumens 25 of the filter 22 (see Figure 1A) and around the ring 20. Each ring 20 has a first sight-glass reservoir 30 attached by pipe at the top of each ring 20 (see also Figure 6) which, when processing, contains oily water. A second sight-glass reservoir 32 is

connected with the outlet side 23 of the filter 22, and receives clear water that has passed radially outwardly from the ring, through the multiple membranes 25 fused to the lumens (channels) of the filter 22 (Figure 1A). Oily water feed from a pressurized feed system 40 passes by way of connection 56 into the ring 20, being admitted on demand through a normally closed solenoid valve 44. During normal processing operation of the ring 20, oily water is introduced through valve 44 and clear permeate water, essentially free of oil, exits through reservoir 32, past normally closed valve 64 and finally out through permeate water meter 71 before leaving the system.

During shut-down the membrane surfaces of the lumens 25 enclosed in filter module 22 need to be protected from fouling with oil. Fouling of membrane surfaces normally occurs on shutdown when cross-flow velocity of oily water traveling through the lumens, across membrane surfaces, is lost while the ring is still under pressure. In these circumstances microscopic oil droplets move radially outwards onto the surfaces 25, fouling the membrane. This is prevented in the subject system, when normally-closed valve 64 (which is held open during processing) closes due to power loss. This closure locks all process permeate water within the system and at the same time normally-open valve 67 (held closed during processing) now opens due to loss of power. Behind valve 67 is pressurized air acting inwards, being at least equal to the ring 20 pressure (acting outwards). This applied air pressure suffuses clear permeate water over the membrane surfaces of the lumens 25, so that the membrane surfaces of

lumens 25 are protected from any tendency of the oil droplets in the ring to adhere to, or to migrate through the membrane.

The ring 20, has a safety line in case of the generation of undue pressure spikes, most likely associated with a cleaning operation. This safety line includes a first, high pressure release valve 45 (H.P. PRV), a pressure switch 47 and a second, low pressure relief valve 49 (L.P. PRV) which sustains pressure a sufficient time for the interposed pressure switch 47 to actuate if the ring 20 pressure exceeds a set safe maximum. During a cleaning operation cycle using hydrogen peroxide from tank 83, the pressure in the ring can build up very rapidly, from oxygen gas released under conditions of heat and agitation and the associated rapid oxidation of organic contaminants present in the ring. In the occurrence of such a pressure "spike", the operation of the first, inboard H.P. PRV 45, (set at 80 psi) protects the processor. The second, L.P. PRV 49, (set at 30 psi) sustains back pressure long enough for the pressure switch 47, (set at 20 psi) and located between the two PRV's, to operate, so as to signal the PLC to shut down the ring pump, thereby terminating its heat generating function. During a normal cleaning cycle high heat alone determines when the circulation pump 28 shuts down upon triggering the temperature transducer 33. However when using hydrogen peroxide two different triggers can shut down the circulation pump 28. The temperature transducer 33 is one and pressure switch 47 is the other. The pressure generated on occasion when using hydrogen peroxide to clean membranes in an enclosed ring can generate destructive pressures very quickly at elevated temperatures as oxygen gas is released

during cleaning as organic contaminants are oxidized. During high pressure spikes pressure switch 47 is triggered and untoward pressure is released out PRV 49. The moment switch 47 sends a signal to the PLC pump 28 is shut down.

The oily water reservoir tank 134 (see also Figure 3) is a pressure vessel having a high level switch (HLS) 46 and a low level switch (LLS) 48, which control the level of oily feed water within the tank 134. A pressure air line 50 with normally-open valves 52, and normally-closed dump valve 54, are used to pressurize the tank 134, and to depressurize it when being re-filled or made-up with oily feed water.

The feed water delivery line 56 which connects to the rings 20 has a safety switch 41 within reservoir 42 which is integral to line 56. If pressurized air and not pressurized oily water is being delivered to the rings 20 in a failure or operator error situation, then the float switch 41 at the top of reservoir 42 would drop due to reservoir 42 now being filled with air. This failure, signaled by switch 41 to the PLC controller would result in the shutting down of all the rings 20.

In the case of a centrally controlled operation, this action would be reported by the PLC controller via modem and phone lines to a server computer at head office.

Reverting to the description, sight-glass reservoir 32 connects through a pipe line 62 to two valves that are teed off this line 62. One line goes to an air line beyond valve 67. The other line is a normally-closed permeate (process water) drain valve 64. Valve 67 is a normally-open air safety valve which is energized

and held closed when the processors 20 are operating. In the event of an electrical power failure (or a controlled shut-down), valve 64 closes, locking-in all permeate water and valve 67 rapidly opens, allowing air pressure (at approx. 60 psi) to back-pulse treated permeate water backwards through the ceramic filters, into the rings 20, to off-set the internal oily water pressure in rings 20. This approach greatly lessens the likelihood of oil droplets in the unprocessed water within the rings 20 from fouling the lumen membrane surfaces 25. The off-set pressures means that no oil flows into the membrane surfaces, to foul them.

The first sight-glass reservoir 30 contains a stainless steel float switch 60, and connects with a common line 66 that tees to a normally-closed air line valve 68 and a normally-closed oily concentrate purge valve 70. As oil is concentrated during the operation of the processor oily concentrate is periodically purged out of the system at valve 70. When normally closed valve 70 is opened pressurized air pushes out any liquid in reservoir 30 and ring 20 when a ring bottom drain valve 88 is also opened. Each ring 20 includes a ring flow meter 74 located upstream of the intake to pump 28, for measuring the flow velocity in the ring 20. The maintenance of correct ring flow velocity is important.

The outlined descriptions can be followed using Figure 7, together with Figure 1, Figure 7 being a detail of the series portion 24 of Figure 1.

The cleaning liquid series 24 includes three pressure tanks 80 and one pressure tank 83, served by air pressure lines 87 and 85 respectively and operating through common pressure regulator 82. The tanks 80 of chemical solution have their internal pressure controlled by normally-open air supply valve 84, and

normally-closed solenoid dump valve 86. Chemical solution tank 83, containing hydrogen peroxide, has no such “in” and “out” air control because the chemical solution content in the tank is simply depleted over time and not reused, hence pressure is applied at all times.

Each tank 80 and 83 has an outlet pipe 90 connecting by a common bus 92 that serves the two rings 20 through ring access valves 96 and 98. Each outlet pipe 90 has a normally-closed solenoid valve 94. A tap water inlet line 97 has a normally-closed solenoid valve 99, that admits rinse water through common bus 92 to the rings 20. A pressure switch 100 is connected to ring 20 and set at a low pressure value as a safety shut down connected to the PLC in the event that ring 20 loses pressure in a critical fault situation.

In Figure 1A, the location of the lumens within the filter 22, and the lumen membrane filter coatings 25 are shown, together with the filtrate collection annulus 23.

Referring to Figure 2, the elements of the ring 20 are shown in their respective locations within a cabinet 35. The system ancillary support equipment is contained in the back of the cabinet, being equivalent to that shown in Figures 4B and 5. Referring to Figures 4B and 5, the ancillary support equipment of the system is contained within the cabinet, being located at the rear of the cabinet, behind the two-ring, two ring arrangement of Figure 4A. It consists of a pair of 10 micron pre-filters 81; the oily water reservoir 134; a back-up air compressor 57 connected to its air storage tank 77; cleaning chemical reservoirs 80 and 83, and a pump 104 used to transfer liquid between site storage tanks.

Referring to Figure 3, the oily water feed system 40 has a pressure tank 134 with an oily water inlet 51 connected to pump 53 which moves oily water through 10 micron pre-filters 81 and ultimately through pipe 133 into pressure tank 134. Tank 134 fills under the action of pump 53 until the oily water level rises to reach float switch 46 (HLS). At this point under the control of the PLC, pump 53 stops, air dump valve 54 closes, and air pressure valve 52 opens, re-pressurizing tank 134 which in turn delivers pressurized oily water past delivery tee 129 through water line 56 to rings 20. When the Low Level Switch 48 (LLS) signals that the tank 134 is depleted of feed oily water, the solenoid valve 52 closes, cutting off the pressurized air supply, and the solenoid valve 54 is opened, thus venting the tank 134 to atmosphere. The low level float switch 48 (LLS) then signals the PLC to admit oily feed water to the tank 134 via pump 53, which continues to fill the tank until the high level float switch 46 (HLS) signals the PLC that the tank 134 is full, and the pump 53 stops.

Turning to Figure 6, the sight-glass reservoirs 30, 32 have a cylindrical sight-glass 110 adjustably secured by bolts 112 and nuts 113 between end plates 114. Elastomeric gaskets 115 provide sealing and resilience to the reservoirs 30, 32. A stainless steel float valve 60 is suspended from the upper end plate 164. Connection nipples 116 are threaded into the end plates 114, for connecting line 66 at the ring reservoir top outlet and line 62 to the module reservoir top position. The bottom inlet of the reservoir 30 connects to ring 20 at its top position. Reservoir 32 is connected from its bottom connection nipple to the module 22 top position.

Figure 7 is the functional equivalent of the cleaning liquid assembly 24 and the associated control valves of Figure 1.

Turning to Figures 8 through 12, commenting sequentially thereon, the process is normally started and run by the PLC, initiating filling the ring or rings with clean water, such as tap water or permeate, and the recirculation pump 28 operated. The oily water circuit is then operated to fill the ring with oily water, and separation is commenced, with permeate passing to drain on a continuing basis.

The process steps set forth herein are preferably controlled by the PLC, in response to signal inputs from respective sensors, referred to above. It will be understood that such control may be effected manually.

Turning to Figure 9, in the event of a process interruption, such as a power failure, the loss in power results in the termination of permeate outflow, and the application of air pressure to the permeate, as a back-pressure, as described above. In this condition, with the reinstatement of power or removal of the interrupting factor, the ring pump 28 is restarted, the permeate outflow valve is re-opened, and separation resumed.

Referring to Figure 10, in order to close down the operation of a ring, the permeate is back pressured, by closure of the permeate outflow valve 64, and opening of air inlet valve 67, to apply air back pressure to the sight glass reservoir 32 (as described above) All pumps and valves are turned off (de-energised), and the stabilized system is maintained under air pressure, with the permeate under back-pressure, so as to maintain the lumen membrane filter

coatings 25 suffused with the permeate water (filtrate), to prevent contamination and blockage by oil droplets depositing on the coatings.

Turning to Figure 11, the concentrated oily water, with about 90 to 95 percent of the original water removed as permeate water, and having an oil concentration of about 35 to 40 percent, is removed from the ring. During this phase of the operation the ring circulation pump continues to operate. The permeate drain valve 64 is closed, and valve 44 is opened to admit oily water to the ring 20 from the feed system 40. The normally-closed oily concentrate purge valve 70 is opened, to drain off a portion of the concentrated oily water from the ring. The valve 70 is then closed, the permeate drain valve 64 is opened, and the separation process resumed.

Referring to Figure 12, the ring is drained of oily water, which is replaced by rinse water, either tap water or recycled permeate, and pumped around the ring.

The ring is then back-filled with one of the cleaning solutions selected from the cleaning liquid series 24. The ring access valves are then all closed, and the circulation pump 28 operated, circulating the cleaning solution through the ring to raise its temperature. The cleaning solution is then passed by air pressure gradient, from the sight glass reservoir 30, through the lumen membrane coatings 25 to the sight glass reservoir 32, and then reversed back to the reservoir 30. This oscillation takes place a number of times, and the cleaning cycle then terminated, usually by return of the cleaning solution to its respective tank.

The ring is then re-filled with rinse water, and the pump 28 operated, to flush the

ring. The rinse water is then dumped to drain, the ring re-filled with oily water, and the separation cycle is re-commenced.